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REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	Final Report (7/1/95-6/30/98)

4. TITLE AND SUBTITLE
Plasma Based Devices

5. FUNDING NUMBERS
DAAH04-95-1-0413

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
ARO 34397.4-PH

11. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

19981222 101

13. ABSTRACT *(Maximum 200 words)*

The most important result relates to the reduction of emissions from NOx sources, and is basically a breakthrough in energy efficiency, based on the application of a transient, short-pulse plasma. The project was a study of physics and applications of plasma devices, and as a result of promising early data, focused on the use of transient plasma devices for NOx remediation.
The most important results are:

- A cost-effective regime, maintaining the simplicity of a pulsed discharge, was successfully found.
- The pulsed discharge, a "plasma muffler", achieves results of 30% NOx reduction, requiring ≤10eV/molecule energy cost for flow rates from operating diesel engines, corresponding to operating efficiencies that would be useful for the transportation industry.
- The role of transient discharges in this process is found to be key, and a preliminary, phenomenological rationale has been found.
- Further research leading to the understanding of the transient processes, and the subsequent chemistry, promises many new applications.
- Preliminary results of Laser Induced Flourescence (LIF) studies are now available.
- Low energy cost was found to be driven by current density, so that an efficient operation at a low energy cost is actually better at low current densities.
- Power modulator design, and reactor design, are found to be interrelated.
- New reactor and power modulator designs have been developed, and, following the goals of the previous work as well as the requirements for many practical implementations, 'miniaturization' of the power conditioning is under development.

14. SUBJECT TERMS	15. NUMBER IF PAGES
electron beams, electron acceleration, plasma processing, laser induced flourescence(LIF), NOx emission, high power switches	4
	16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

(1) LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP:

Refereed Publications:

"Acceleration of electrons to > 0.5 MeV during space-charge neutralization of a 20 keV transient electron beam," K. Frank, J. Christiansen, T. Redel, R. Stark, M. Setter and M. A. Gundersen, Appl. Phys. Lett., **68** (10), 1424 (1996).

"Energy efficient plasma processing of gaseous emission using short pulses," V. Puchkarev and M. Gundersen, Appl. Phys. Lett. **71** (23), 3364 (1997).

"Laser-induced fluorescence images of NO distribution after needle-plane pulsed negative corona discharge," G. J. Roth and M. A. Gundersen, IEEE Trans. on Plasma Sci. (submitted June 1998).

"Plasma processing of diesel exhaust by pulsed corona discharge," V. Puchkarev, G. Roth, and M. Gundersen, 1998 SAE International Fall Fuels and Lubricants Meeting, San Francisco, CA, October 19-22, 1998.

Other Publications:

"Studies of the physics and technology of non-thermal plasma treatment of diesel emission," V. Puchkarev, G. Roth, M. Gundersen, I. Yampolsky, G. Kirkman and M. Choi, Proceedings of the DOE Workshop on Diesel Emission Abatement, San Diego, CA, July 24-27, 1995.

"Plasma treatment of diesel exhaust," M. Gundersen, V. Puchkarev and G. Roth, Proceedings of the Eighth ONR Propulsion Meeting, San Diego, CA, October 11-13, 1995.

"Plasma treatment of diesel exhaust," M. Gundersen, V. Puchkarev, G. Roth, and N. Helgeson, 9th ONR Propulsion Meeting, Washington, DC, Sept. 9-12, 1996.

"Emission control using plasmas," G. Roth and M. Gundersen, in "Modern Developments in Propulsion and Combustion," Ed. G. Roy, Taylor & Francis (to be published).

"High power switches," M. Gundersen and G. Roth, in "The Handbook of Accelerator Physics and Engineering," Ed. A. Chao, (to be published).

"Efficient, effective, non-thermal plasma aftertreatment of diesel NOx," M. Gundersen, V. Puchkarev and G. Roth, Proceedings of the 10th ONR Propulsion Meeting, Monterey, CA, Oct. 7-10, 1997.

"Power modulators for control of transient plasmas for environmental applications," V. Puchkarev and M. Gundersen, Proceedings of the 23rd International Power Modulator Symposium, Rancho Mirage, CA, June 22-25, 1998.

"A Power modulator for advanced klystrons," I. Yampolsky, V. Puchkarev, and M. Gundersen, Proceedings of the 23rd International Power Modulator Symposium, Rancho Mirage, CA, June 22-25, 1998.

"Energy efficient plasma treatment of diesel emission using a short pulse discharge: Physics and applications," V. Puchkarev, G. Roth and M. Gundersen University of Southern California, Los Angeles CA, Proceedings of the DEER Conference, Castine, ME, July 6, 1998.

"Plasma processing of diesel exhaust by pulsed corona discharge," Victor Puchkarev, Gregory J. Roth, and Martin Gundersen, Proceedings of the 11th ONR Propulsion Program Contractors Meeting, Palm Beach, FL, August 17-19, 1998.

(2) LIST OF PARTICIPATING SCIENTIFIC PERSONNEL: M. Gundersen
V. Puchkarev
G. Roth

(3) REPORT OF INVENTIONS: Pollution treatment cells energized by short pulses – U.S. Patent 5,603,893, Feb. 18, 1997

This invention, and related research is receiving international attention for pollution abatement applications. (see below, under technology transfer)

(4) SCIENTIFIC PROGRESS AND ACCOMPLISHMENTS:

The most important result relates to the reduction of emissions from NOx sources, and is basically a breakthrough in energy efficiency, based on the application of a transient, short-pulse plasma[1]. The project was a study of physics and applications of plasma devices, and as a result of promising early data, focused on the use of transient plasma devices for NOx remediation.

The most important results are:

- A cost-effective regime, maintaining the simplicity of a pulsed discharge, was successfully found.
- The pulsed discharge, a "plasma muffler", achieves results of 30% NOx reduction, requiring ≤10eV/molecule energy cost for flow rates from operating diesel engines, corresponding to operating efficiencies that would be useful for the transportation industry.
- The role of transient discharges in this process is found to be key, and a preliminary, phenomenological rationale has been found.
- Further research leading to the understanding of the transient processes, and the subsequent chemistry, promises many new applications.
- Preliminary results of Laser Induced Flourescence (LIF) studies are now available.
- Low energy cost was found to be driven by current density, so that an efficient operation at a low energy cost is actually better at low current densities.
- Power modulator design, and reactor design, are found to be interrelated.

- New reactor and power modulator designs have been developed, and, following the goals of the previous work as well as the requirements for many practical implementations, 'miniaturization' of the power conditioning is under development. The first stage, a thyratron based system, has been developed in collaboration for commercial applications, and technology transfer of the system has been demonstrated with applications within the DoD, and in the diesel industry.

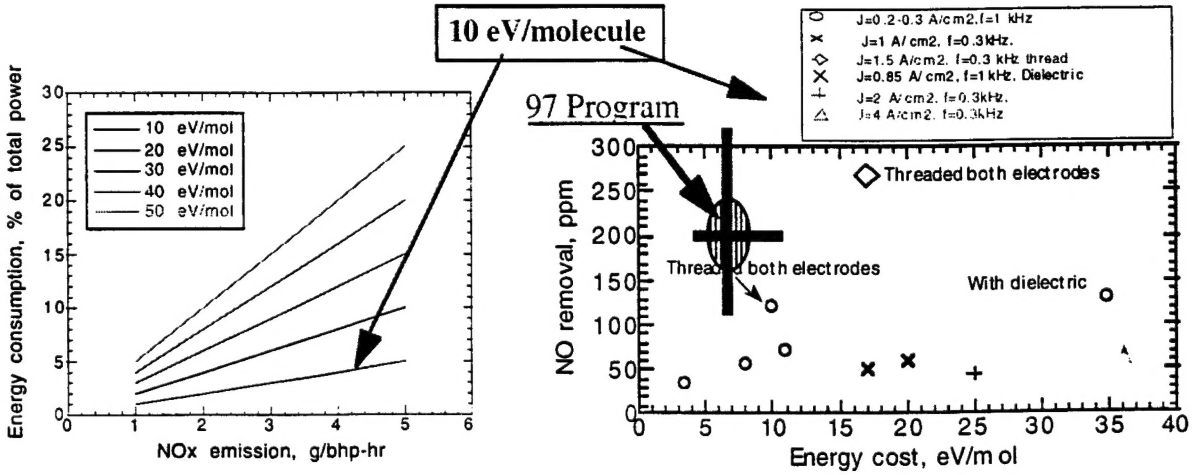

Figure 1. Summary of data taken with real diesel emission. Most important results are shown on right, with energy cost in eV/molecule ≈7eV/mol. for ≈200 ppm total NOx reduction from a diesel engine operating with a load. Additional data for a range of test conditions is provided. Some of this is described in ref. 2. Further detailed data will be published, however, results are seen as useful for actual applications, and industry technology transfer is underway. On left is shown energy consumption as function of NOx emission in industry units, with conversion factors for various eV/mol.

TECHNOLOGY TRANSFER

We have interacted extensively with diesel, automotive, electronics, and catalyst companies, as well as various parts of the DOD. Technology based on this research is now in use at US Naval Port Hueneme for applications to VOC reductions, and at the major diesel engine manufacturers. Approaches related to the patent above are in use a most major electronics firms interested in this technology, including Siemens, Motorola, Hughes, Englehard, and smaller companies such as NOXTECH in Irvine, CA, the diesel companies Cummins, Detroit Diesel Corporation, and Caterpillar. Related methods are under study at Livermore and Los Alamos. Major efforts are underway in Europe and Asia, and there is considerable potential for foreign competition for these commercial applications. Automobile companies visiting USC include Ford and GM. Some

proprietary interactions are underway to further exploit commercial possibilities for clean air applications.

Related news articles:

1. "Zapping pollution, not missiles" -- *University of Southern California Chronicls*, June 17, 1996.
2. "Death Rays to Zap Diesel Pollution?" -- *Business Week*, July 1, 1996.
3. "Pulsed Power Cleans Diesel Exhaust" -- *Inside R&D*, July 1996.
4. "Star Wars Scientist Takes Aim at Smog" -- *Pasadena Star-News Business*, August 1, 1996.
5. "High-Tech Help for Dirty Diesels" -- *MIT Technology Review*, May/June 1997.
6. "Short Pulses Show Promise for Treating Pollution" -- *The Ballistic Missile Defense Organization Update*, Spring 1997.

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[1] "Plasma Treatment of Diesel Exhaust," M. Gundersen, V. Puchkarev, G. Roth, and N. Helgeson, Proc. 9th ONR Propulsion Meeting, G. Roy and K. Kailasanath, Ed., 1996, available through the Office of Naval Research.